



Using the hidden Markov model to capture quality of care in Lombardy geriatric wards



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ABSTRACT

Quality of care is an important aspect of healthcare monitoring, which is used to ensure that the healthcare system is delivering care of the highest standard. With populations growing older there is an increased urgency in making sure that the healthcare delivered is of the highest standard. Healthcare providers are under increased pressure to ensure that this is the case with public and government demand expecting a healthcare system of the highest quality. Modelling quality of care is difficult to measure due to the many ways of defining it. This paper introduces a potential model which could be used to take quality of care into account when modelling length of stay. The Coxian phase-type distribution is used to model length of stay and the associated quality of care incorporated into the Coxian using a Hidden Markov model. Covariates are also introduced to determine their impact on the hidden level to find out what potentially can affect quality of care. This model is applied to geriatric patient data from the Lombardy region of Italy. The results obtained highlighted that bed numbers and the type of hospital (public or private) can have an effect on the quality of care delivered.

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1. Introduction

Quality of care is a multifaceted concept, whose incorporation into scientific study as a result is deemed difficult but one of great importance and interests [1]. In 1855 (during the Crimean War), Florence Nightingale noticed that soldiers operated upon in large hospitals were more likely to die than those operated upon in smaller hospitals. She identified that poor sanitation and the rapid spread of infection from patient to patient in large hospitals was the cause, so she set about doing something to improve the sanitary conditions in English field hospitals. More than a century later, there is still great interest in characterising hospitals that provide better or worse care with the aim of improving the quality delivered [2].

Healthcare systems across Europe and further afield have come under increased pressure and scrutiny in recent years, with governments wanting hospitals to deliver the highest standard of care to their citizens while managing and sticking to tight deadlines

and budgets. Many European countries are encountering a growing older population and this comes with many problems for not only governments but also healthcare providers [3]. Elderly individuals tend to spend longer in care than the rest of the population due to complex and time consuming medical conditions and rehabilitation. This in turn puts a strain on the hospital's budget, with healthcare managers coming under increased pressure to make sure that the hospitals deliver the best quality of care available but at the same time effectively and efficiently managing an already stretched budget [4].

A high standard of healthcare is of vital importance to any country. The measure of the quality of the healthcare system is increasingly relevant given the growing elderly populations across Europe and the need to deliver the highest possible standard of care. This paper concentrates on the Lombardy healthcare system, in particular geriatric wards within this system.

Quality of care can and has been defined in many ways as it is not amenable to a single performance measure. The Institute of Medicine defines it as having the following six key domains [5]:

- (1) **Effectiveness:** This refers to the extent to which an intervention produces its intended result, and the concept of appropriateness; concentrating on whether interventions or services are provided to those who would benefit from them and withheld from those who would not.

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- (2) **Access:** Access monitors waiting times, with lower waiting times for patient procedures being more beneficial.
- (3) **Capacity:** This takes into account the number of medical staff, bed numbers, along with how well equipped the hospitals and or surgeries are as well as the budget allocated/available to each provider.
- (4) **Safety:** Safety is concerned with infection control while the patient is in hospital and the elimination of unnecessary risk of harm to patients.
- (5) **Patient Centredness:** This measures how patients rate the quality of care that they are receiving whilst in hospital.
- (6) **Equity:** Equity is concerned with significant inequalities in life expectancy and mortality from major diseases between the least and most deprived groups.

Quality of care has previously been incorporated into studies using the number of deaths [6], readmission [7] and length of stay of patients [8] as common proxies for its measurement. The benefit of using one of these proxies as a measurement of quality of care is that they are easily understood and common variables within healthcare data.

Each of these proxies have limitations when using them as a measurement for quality of care. Using death rate might not be the best measure of quality of care as it is not necessarily the quality that the hospital offers that causes the outcome but rather the disease or injury endured by the patient. Given that it is geriatric wards that this paper will consider, death is more likely amongst this group of individuals than any other due to old age or the lowered ability to recover from disease and infection. Readmissions also create limitations in the data. Elderly patients tend to be admitted into hospital due to one condition but in fact they may be suffering from several other ailments. As a result they generally tend to spend longer in hospital due to the variety of illness that many of them suffer from at any one time. Therefore to use length of stay data as a proxy, very long length of stays as well as short length of stays (which are mainly attributed to patients who die) could serve as flagging up potentially poorer quality of care delivered to these patients [9]. Holt et al. [10] reports that length of stay is one of the most important and valid proxies to measure quality of care. Given that there are many different ways to define quality of care the use of a proxy measure may help in overcoming the complexities of modelling it. Due to length of stay being related to the outcome of patients, and that the data used in this paper does not have readmission information, length of stay was used and quality of care inferred from it.

Quality of care is difficult to measure due to its many factors, internal and external [11]. It is however of vital importance to healthcare systems and is a concept which should be ascertained as governments and patients expect their healthcare system to deliver the best care possible. Developing it into a model would be beneficial to the healthcare system. This could help healthcare managers as they strive to achieve a hospital which is run effectively and efficiently while maintaining a high quality of care. It is also a good means of ensuring that there are no inequalities in the system. Within Italy a model which encapsulates quality of care would be advantageous, as each of the twenty regions run healthcare systems which are slightly different from each other. A model with the potential of evaluating the quality of care provided by each of the region's healthcare facilities could be used to highlight which regions are consistently delivering a good quality service and which are not. This could possibly help those regions who are performing worst in reorganising and improving their healthcare. It could also help in the allocation of funding to each of the regions healthcare budgets from the main Italian government. Since quality of care cannot be observed directly, one potential way of modelling it is to use a Hidden Markov model in which quality is the hidden or unobservable layer. Length

of stay has been seen as an indicator of quality of care and it has been shown that the Coxian phase-type distribution gives a good representation of length of stay. In this paper the Coxian phase-type distribution has been combined with the HMM, thus giving the effect of a hidden layer (representing quality) being incorporated into the Coxian phase-type distribution. The Coxian phase-type distribution with a hidden layer will be applied to healthcare data from geriatric wards in the Lombardy region of Italy. Covariates relating to the hospital which potentially affect quality of care will be incorporated into the model. This model will subsequently highlight when the quality of care delivered by the hospital has changed and how quality of care affects a patient's length of stay. It will also highlight covariates which can affect quality of care. This paper is arranged as follows. The next section discusses the dataset used. Section 3 contains the models used in addressing this problem; the Hidden Markov model and the Coxian phase-type distribution. The application of the model to the Italian healthcare data is detailed in Section 4. The final section of the paper gives conclusions and future research.

2. The Italian healthcare system

The Italian healthcare system was established in 1978 and provides universal healthcare coverage throughout the Italian State to all citizens regardless of the individual's social status. Italy is made up of 20 regions which differ in terms of demography, economic development, healthcare infrastructure and healthcare expenditures. These differences can be seen in a North–South divide in Italy. The northern part of Italy is the industrial and economical hub. The regions in the north of the country have the largest populations within Italy and also have the highest GDP per capita; they also have larger elderly populations [12]. These regions tend to be more assertive in terms of the political power that they have, whereas the southern regions tend to be more timid. Given that the northern regions have greater populations and are more industrial the taxes collected by the regional governments are therefore higher. Each region has the power to decide how much of the regional taxes should be spent on their healthcare system, with the northern regions getting more taxes has meant more spend on healthcare. This has led to the hospitals in the north of the country having better equipment and screening policies, which may have led to the better survival rates which have been seen for patients treated in the north [13]. To date, there is no work conducted to assess the quality of geriatric care within the regions in Italy yet elderly patients are going to make up most of the patients receiving hospital treatment in the near future. Analysing the care delivered by the hospitals to elderly patients in preparation for the increasing ageing population, has inspired this paper.

The data used in this study is from an Italian administrative dataset, which contains all of the geriatric wards¹ in the Lombardy Region in the year 2009. The Lombardy region is situated in the north of Italy and is one of the top ranked regions in Italy for socio-demographic indicators. It has a population of about 10 million residents which is about 16% of the total Italian population and economically it is amongst the most competitive areas in Europe. About a fifth of Italy's GDP is produced in the region making it one of the most populous and richest regions in the country [12].

¹ The dataset refers only to the patients that used the National Health System. In Italy, while public hospitals are generally completely financed with public funds, private hospitals rely on a mix of public funds (counterpart of services provided to citizen covered by the National Health System) and private ones (coming from citizens acquiring services that add to, or replace, those provided by the National Health System). In the dataset, we consider both hospitalisations in public hospitals and hospitalisations in private hospitals but covered by the National Health System.

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